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EXPERIMENTAL EVALUATION OF PISTON USING ALUMINIUM ALLOY (LM24) REINFORCED WITH SIC AND GRAPHITE

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ABSTRACT

Aluminium has a huge stipulation in the field of automobile, aerospace and other versatile engineering applications in order to embellish the requirement in those areas. But this technological progress needs something new other than aluminium. Metal matrix composite (MMC) can be an answer to that issue. In this study, Aluminium LM24 alloy is taken as a base matrix material, whereas silicon carbide and graphite particulate is used as reinforcement. Stir casting technique, which is a liquid state process, is used for the fabrication of the MMCs. Four different MMC specimens were produced with 5% SIC and 5% graphite, 6.5% SIC and 3.5% graphite, 7.5% SIC and 2.5% graphite are used as samples. Mechanical properties like tensile strength and hardness are studied on the fabricated composite specimens. Morphological studies are also studied on the tested samples using Scanning Electron Microscopy (SEM) to observe the bonding between the matrix and reinforcements. The results were plotted and graphically presented to express those materials characteristics. From the tensile results, it is observed that the strength increased with increase in reinforcement percent, thereby decrease in elongation percent. Hardness also increased with reinforcement percent in the composite sample. In this investigation, we prepared a piston with reinforced composition of Group-2 (6.5% SIC and 3.5% graphite). This prepared piston is made to run on a diesel engine and evaluated the performance characteristics of a diesel engine.

KEYWORDS: MMC, Mechanical Properties, SIC, Graphite, Aluminium & SEM

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Original Article

1. INTRODUCTION

Metal matrix composites (MMCs) have many prospective applications owing to the fact that of the distinctive property blends that can be obtained. MMCs have been emerged to counter the stipulation for materials with high specific strength, stiffness and wear resistance.

Aluminium alloy is going to replace the ferrous material in engineering applications. Conventional aluminium is ductile and renowned for their terrible wear resistance. This problem will be overcome by including flinty ceramic particles as a reinforcement to improve its properties like elastic modulus, hardness and strength at elevated temperatures, non-toxic, non-magnetic. MMCs are fabricated by integrating the ceramic particulates into a molten metal matrix phase and then it is cast in moulds as per the demand.

Chauhan *et al.* [1] investigated on the alumina reinforced MMCs by varying its reinforcement percent. The properties like tensile strength were observed to be increased with increase in Al_2O_3 and Fly ash. The change in these properties is observed to be moderated up to 10% addition of reinforcement and marginal changes were observed with 15 and 20% of reinforcements. Boopathi *et al.* [2] worked on the silicon carbide and fly ash

reinforcements into the aluminium (Al-2024) metal matrix hybrid composites. Their work showed an increase in tensile strength for hybrid composite but also observed that the elongation of unreinforced aluminium was more than that of hybrid MMC when compared. Mohanavel *et al.* [3] investigated on AA7075 alloy matrix composites reinforced with a different weight fraction of fly ash through the stir casting process. The mechanical properties of the composite resulted in increased hardness and tensile strength with the increase in reinforcement content. The superior mechanical properties were achieved at AA7075/12 wt.% fly ash composites. Sridhar *et al.* [4] worked on the characteristics of A356 alloy reinforced with bottom ash is carried out by the stir casting method. From this work, it was suggested that the use of bottom ash is an economic alternative as the bottom ash shows a great influence input to the waste minimization as well as resources preservation. Thamizhvalavan *et al.* [5] investigated on the Abrasive Aqua Jet (AAJ) machining of a hybrid metal matrix which consists of Al 6063 reinforced with boron carbide (B_4C) and zirconium silicate ($ZrSiO_4$) in the form of particulates. From their work, the results showed an elevated abrasive flow rate (400 g/min), higher aqua jet pressure (300 MPa), and lower traverse rate (30 mm/min), lower surface roughness, attains higher material removal rate and kerf taper angle. Thirumalai Kumaran *et al.* [6] investigated on dry sliding wear behaviour of aluminium matrix alloy (AA6351) on the wear test parameters with 5 wt% boron carbide-reinforced hybrid MMCs and 5 wt% silicon carbide. From their work, improvement of wear resistance was attained with the inclusion of a small amount of the said materials. Atrian *et al.* [7] studied the characterization and synthesis of Al7075 MMCs reinforced with SiC along with their mechanical behaviour. The increase in strength and hardness is perceived by the inclusion of nanoparticles into the matrix. Dharmalingam *et al.* [8] investigated the dry sliding performances optimization on the aluminium hybrid MMCs using Taguchi based grey relational analysis. The results of their work presented that in controlling the friction and wear behaviour of composites, the three test parameters had a significant effect. Praveen Kittali *et al.* [9] reviewed the effects of Al_2O_3, B_4C, Gr, Y_2O_3 and SiC reinforcements on the mechanical and tribological behaviour of an AMMCs produced by different techniques such as stir casting, powder metallurgy, etc. Veeresh Kumar *et al.* [10] experimentally compared the results of Al6061-SiC and Al7075-Al_2O_3 composites. The increased percentage of these reinforcements accorded to the increased density and firmness of the composites. The uniform distribution of the particles in the matrix system is disclosed by the study of micro-photographs of composites. The theoretical density values of the composites are secured using the rule of mixture for composites have concurred with that of experimental density values. The dispersed SiC in Al6061 alloy and Al_2O_3 in Al7075 alloy contributed to enhance the tensile. Din Bandhu *et al.* [11] investigated on MMCs by taking Al 7075 as a base matrix material, whereas ceramic materials like SiC, Al_2O_3, B_4C and TiB_2 are used as reinforcements. Four different MMC specimens were produced with 15% SiC, 15% Al_2O_3, 15% B_4C and 15% TiB_2. Mechanical properties like hardness, tensile strength and impact strength were studied for the prepared specimens. Sujan *et al.* [12] studied the capabilities of stir cast SiC and Al_2O_3 reinforced MMC materials. Results of their work revealed that the newly fabricated material outlay on abrasive wear to be at a lower rate. Being exceptionally weighing less than the conventional grey cast iron material, the Al–SiC and Al–Al_2O_3 composites could be the prospective green materials for implementation, for instance, in making car disc brake rotors in the automobile industry.

In this existing work, stir casting technique is used. A liquid state method is normally put on for fabricating composite materials wherein preheated reinforced materials are added to a molten metal using a stirrer. After proper mixing, the liquid composite material is poured into required moulds. The reinforcement used in the present work is SIC and graphite with matrix material as Aluminium alloy (LM24). The fabricated samples are tested for the evaluation of mechanical properties.

2. MATERIALS AND METHODS

2.1 Composite Fabrication

The synthesis of MMC used in the study was carried out by the stir casting method. An aluminium alloy of LM24 was purchased from Vision castings Pvt. Ltd, Hyderabad, Telangana. Liquid state metal is usually employed for developing composite materials where preheated reinforcement materials are added to the molten metal at a speed of 500 rpm. After the addition of reinforcement, stirring was continued for 4–6 minutes for proper mixing of prepared particles in the matrix. The melt was kept in the crucible for an approximate of half minute in the static condition and then it was poured into the die. The schematic illustration of these steps to fabricate the samples is shown in Figure 1. Keeping the 5% SIC and 5% graphite, 6.5% SIC and 3.5% graphite, 7.5% SIC and 2.5% graphite, such four sets of specimens are prepared for four different compositions. The obtained specimens from the mould are shown in figure 2 and are machined to the desired requirement.

a b

Figure 1: Stages of Preparation of Metal Matrix Composites a) Melting and Stirring b) Pouring.

Figure 2: Fabricated Hybrid Composite Specimens.

Table 1: Composition of Reinforcement

METALS	GROUP-0	GROUP-1	GROUP-2	GROUP-3
SIC	-	5%	6.5%	7.5%
Graphite	-	5%	3.5%	2.5%

2.2 Tensile Test

The tensile test was carried out in computerized Universal Testing Machine (UTM) in room temperature at G. Pulla Reddy Engineering College, Kurnool. The tensile test was conducted on every sample of specimen and the results are calculated for reinforcement of SIC and graphite. The test setup and testing sample holding method is shown in figure 3.

Figure 3: Test Setup for Testing the Composite Samples.

2.3 Hardness Test

To test the hardness, Brinell hardness test was used at the room. The test setup and its testing measurement direction are shown in figure 4. The formula for finding the Brinell Hardness Number (BHN) is given below. The hardness of a LM24 alloy with reinforcement of SIC and graphite is measured by hydraulically pressing a hard ball under a standard load into the specimen. The Brinell Hardness Number is the load divided by the surface area of the indentation. The diameter of the impression is measured with a microscope with a superimposed scale. The Brinell Hardness Number is computed from the below equation: P is the applied load of 500kg. This indicates a good bonding between the base alloy and reinforcement shows the hard particles are successfully dispersed in the metal matrix.

$$BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})}$$

Figure 4: Brinell Hardness Test Setup.

2.4 Wear Test

Wear is the damaging, gradual removal or deformation of material at solid surfaces. Causes of wear can be mechanical (eg., erosion) or chemical (eg., corrosion). Wear test is used to determine the amount of material removal during a specified time period under well defined conditions. To obtain more accurate predictions of wear, it is necessary to conduct

wear testing under conditions simulating the exact wear process. The wear test was conducted on every sample of specimen and the results are calculated for reinforcement of SIC and graphite. The experimental setup for wear test is shown in figure 5.

Figure 5: Wear Testing Machine.

2.5 Piston Manufacturing Process

For all tests, the values of Group-2 (6.5% SIC and 3.5% graphite) is higher when compared to all other groups. Hence, by taking the composition of Group-2, we manufactured the piston with the employment of sand casting method. In the sand casting method, the pouring of molten metal into a sand mold (molds are generally provided with a cavity of the shape to be made) and allowing it to solidify inside the mold. Various patterns are used to create cavity in the molds. Depending on the production quantities, different pattern materials namely, wood, aluminium, ferrous metals are used in practise. In present investigation, wood pattern is used for manufacturing the piston, because of low, moderate and high production quantities.

Figure 6: Manufacturing of Piston by Sand Casting.

Figure 7: Aluminium LM24 Alloy Piston.

Thereafter, an experiment is conducted on a diesel engine using aluminium LM24 alloy piston and determined the performance characteristics of a diesel engine.

2.6 Experimental Procedure

In this exploration, the prepared piston is made to run on a 4-stroke diesel engine with DC generator loading having 5HP as rated power at 1500 rpm is used. Diesel engine setup is demonstrated in Figure 8. Diesel engine specifications are demonstrated in Table 2. The tank is filled with the diesel taken. The pipe should be checked that there should be no air bubbles and the pipe is connected to the engine. The decompression switch is proceeded, so that, there will be no air getting amidst in barrel and the chamber. At that point, motor is to be commenced and it is permitted to get the speed, easily for a couple of moments. By means of the tachometer, speed of the engine is estimated. Now take down the voltmeter, ammeter readings, time taken for utilization of fuel on no load conditions and perusing of manometer. At that point, the motor is stacked by gradually bringing down the copper plate in water rheostat. In the wake of applying of burden on the motor at set point, take down the readings. Same procedure is repeated for different values.

Table 2: Diesel Engine Specifications

Make	Kirloskar Make, Compression Ignition with D.C. Generator
No. of cylinders	one
Bore	80 mm
Coefficient of discharge (C_d)	0.62
Capacity	4 KW
Diameter of Orifice (d)	20 mm
Stroke	110mm
Compression ratio	16:1
Maximum Current	13 amps
Efficiency of dynamometer	80%
Armature voltage	220V

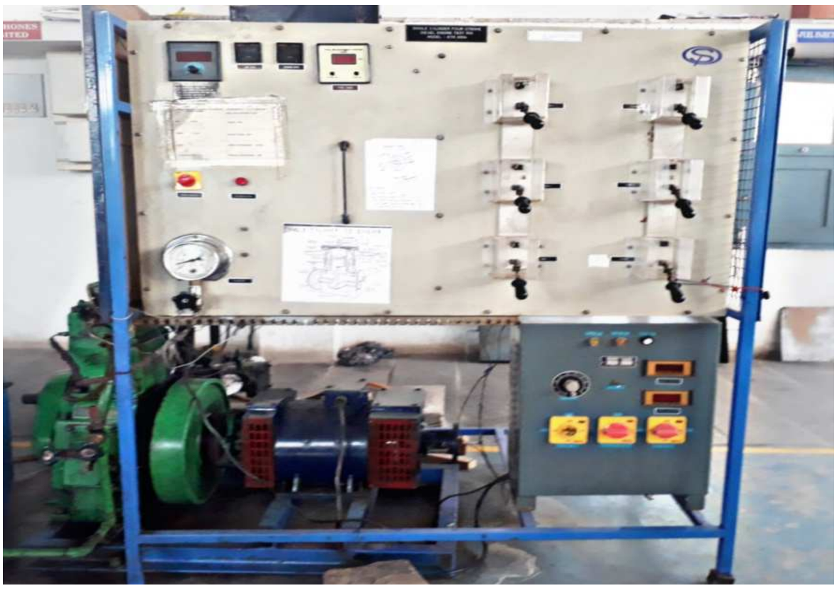


Figure 8: Diesel Engine Setup.

3. RESULTS AND DISCUSSIONS

3.1 Wear Test

The wear test was conducted on every sample of specimen and the results are calculated for reinforcement of SIC and graphite. Graphs are plotted between time versus wear, coefficient of friction and frictional force for all samples.

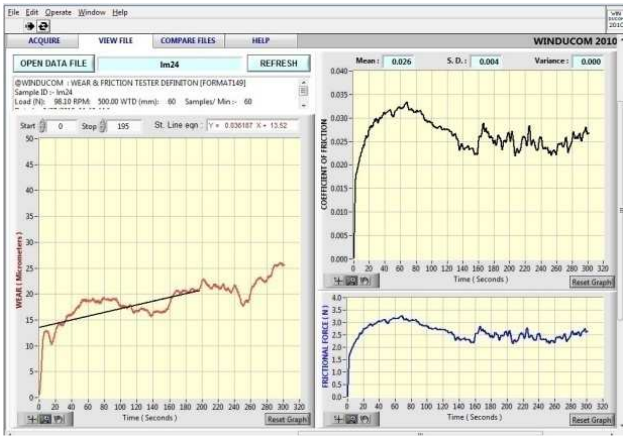


Figure 9: Wear Test Readings for Group-0.

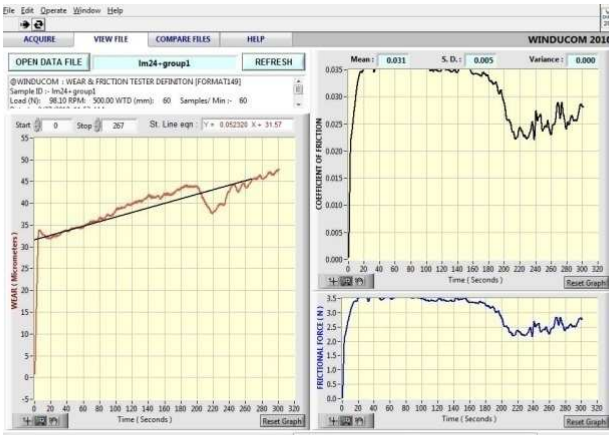


Figure 10: Wear Test Readings for Group-1.

Figure 11: Wear Test Readings for Group-2.

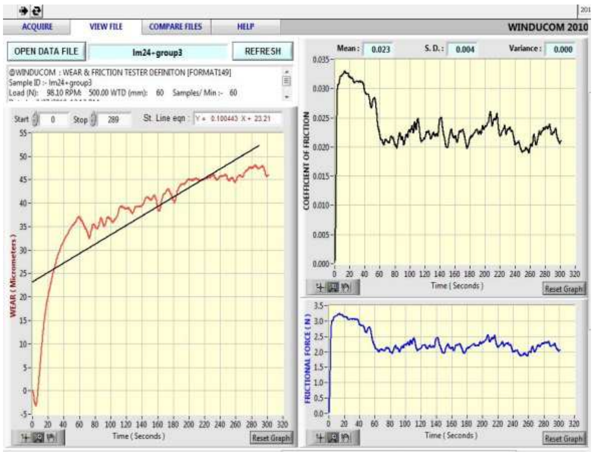
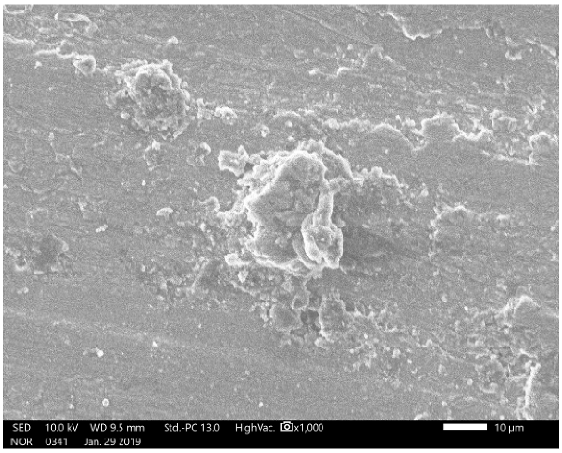
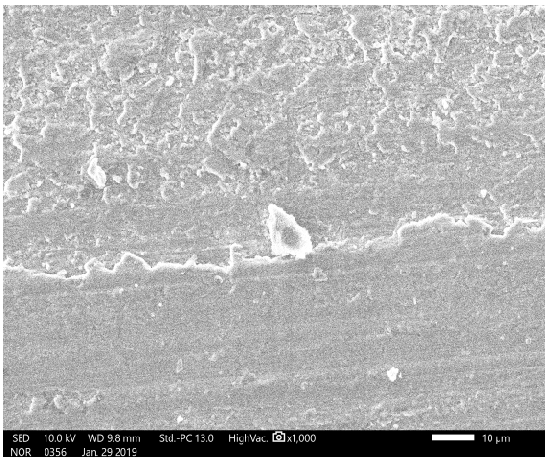


Figure 12: Wear Test Readings for Group-3.

3.2 SEM Analysis

The tensile strength of the composite increases with the addition of SIC and graphite is noted from the universal testing machine for different varying proportions. Due to even distribution of reinforcement into the matrix results in the increase of tensile strength. The reason for the increase in tensile strength is due to the presence of the interfacial gaps between the matrix and the reinforcement, which is unable to transfer the load from the matrix to reinforcing phase as can be seen from the optical micrograph.





a b

Figure 13: SEM Images of Metal Matrix Hybrid Composites a) Group-2 b) Group-3.

3.3 Performance Characteristics

3.3.1 Brake Specific Fuel Consumption

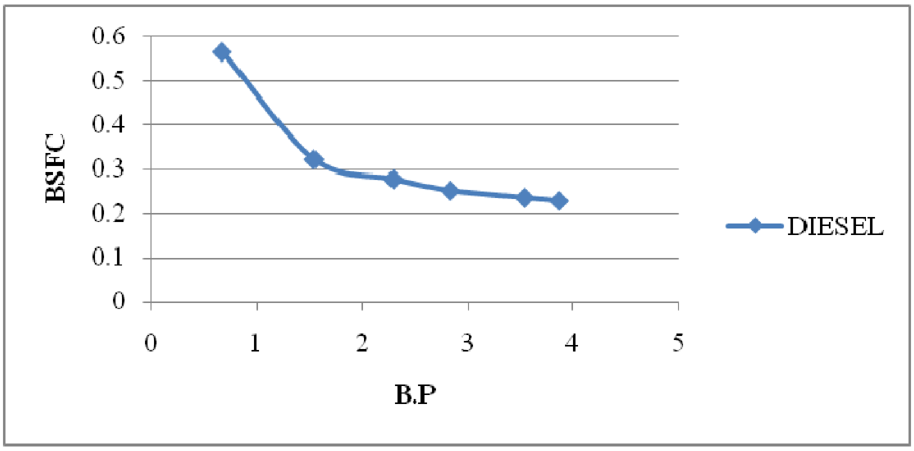


Figure 14: The Variation of BSFC with respect to Brake Power.

3.3.2 Brake Thermal Efficiency

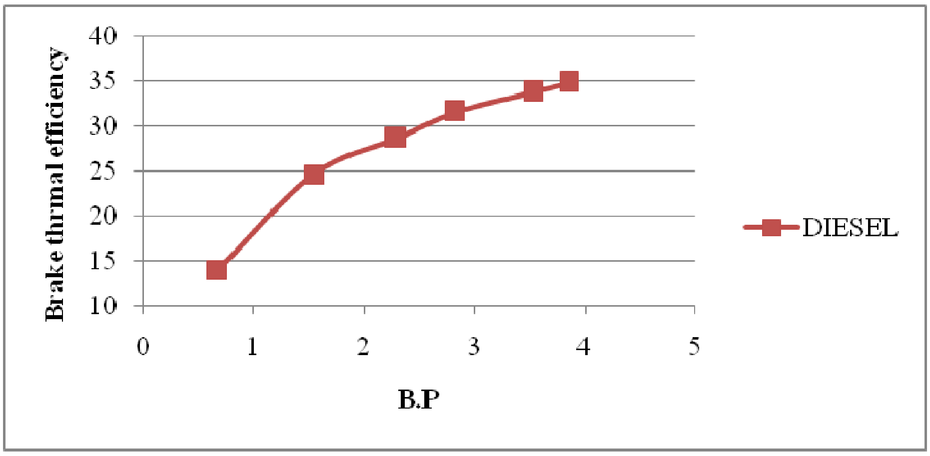


Figure 15: The Variation of Brake Thermal Efficiency with respect to Brake Power.

3.3.3 Indicated Thermal Efficiency

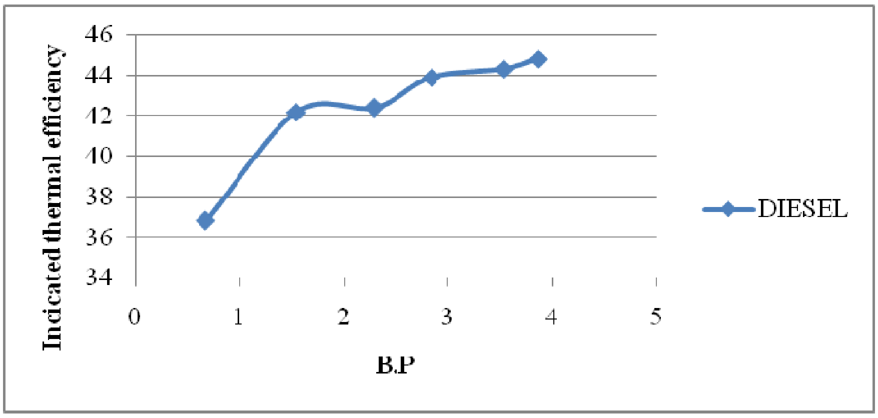


Figure 16: The Variation of Indicated Thermal Efficiency with respect to Brake Power.

3.3.4 Mechanical Efficiency

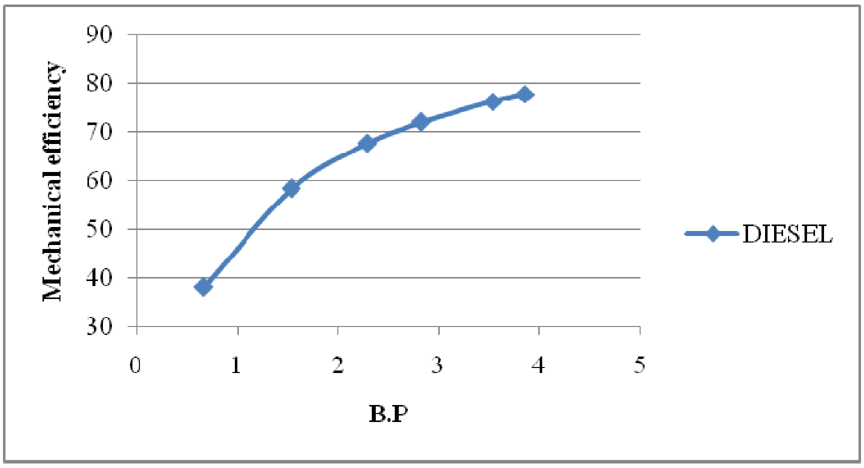


Figure 17: The Variation of Mechanical Efficiency with respect to Brake Power.

3.3.5 Volumetric Efficiency

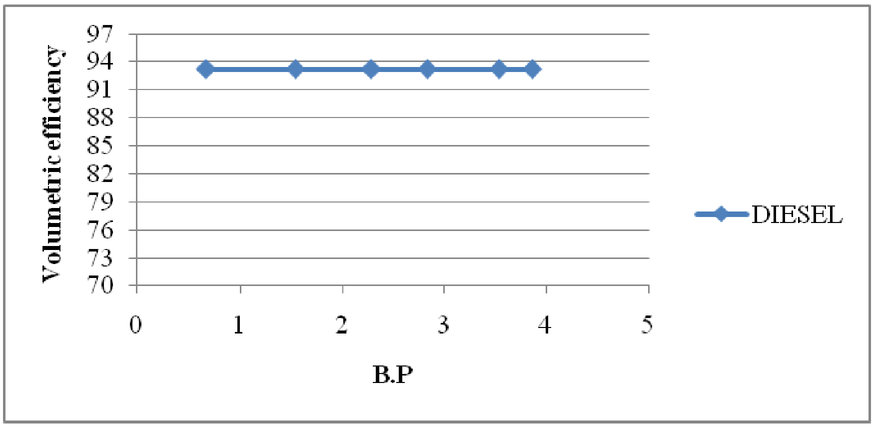


Figure 18: The Variation of Volumetric Efficiency with respect to Brake Power.

4. CONCLUSIONS

We prepared a piston with the reinforced composition of Group-2 (6.5% SIC and 3.5% graphite). This prepared piston is used to run on a diesel engine and evaluated the performance characteristics of a diesel engine. The following conclusions are drawn.

- The brake specific fuel consumption of the diesel is lower at all blends. It is observed that with increase in load, decreases fuel consumption of diesel.
- The brake thermal efficiency and indicated thermal efficiency of the diesel is gradually increases with increase in load.
- The mechanical efficiency of the diesel engine is increased with the addition of load. This is mainly due to less friction.
- The volumetric efficiency of the diesel engine is significantly improved.

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